departing from the scope of the present invention. For example, multiple summations can be utilized by a system of the invention, and not separate summations as described herein. Moreover, by way of further non-limiting example, it will be appreciated that although the terminology used above is largely based on the UMTS CDMA protocols, that the methods and apparatus described herein are equally applicable to DS/CDMA, CDMA2000 1X, CDMA2000 1xEV-DO, and other forms of CDMA.

Therefore, in view of the foregoing, what we claim is:

Wireless Communication Systems And Methods For Long-code Communications For Regenerative Multiple User Detection Involving Implicit Waveform Subtraction

1. In a spread spectrum communication system of the type that processes one or more spread-spectrum waveforms ("user spread-spectrum waveforms"), each representative of a waveform associated with a respective user, the improvement comprising:

a first logic element that generates a residual composite spread-spectrum waveform as a function of a composite spread-spectrum waveform and an estimated composite spread-spectrum waveform,

one or more second logic elements each coupled to the first logic element, each second logic element generating a refined matched-filter detection statistic for at least a selected user as a function of

(i) the residual composite spread-spectrum waveform and

(ii) a characteristic of an estimate of the selected user's spread-spectrum waveform.

2. In the system of claim 1, the further improvement wherein the characteristic is at least one of an estimated amplitude and an estimated symbol associated with the estimate of the selected user's spread-spectrum waveform.

3. In the system of claim 1, the improvement wherein the spread-spectrum communications system comprises a code division multiple access (CDMA) base station.

4. In the system of claim 1, the improvement wherein the CDMA base station comprises one or more long-code receivers, and each long-code receiver generating one or more respective matched-filter detection statistics, from which the estimated composite spread-spectrum waveform is, in part, generated.

5. In the system of claim 1, the improvement wherein the first logic element comprises summation logic which generates the residual composite spread-spectrum waveform based on the relation

$$r_{res}^{(n)}[t] \equiv r[t] - \hat{r}^{(n)}[t],$$

wherein

$r_{res}^{(n)}[t]$ is the residual composite spread-spectrum waveform,

$r[t]$ represents the composite spread-spectrum waveform,

$\hat{r}^{(n)}[t]$ represents the estimated composite spread-spectrum waveform,

t is a sample time period, and

n is an iteration count.

6. In the system of claim 5, the further improvement wherein the estimated composite spread-spectrum waveform is pulse-shaped and is based on estimated complex amplitudes, estimated delay lags, estimated symbols, and codes of the one or more user spread-spectrum waveforms.

7. In the system of claim 1, the further improvement wherein each second logic element comprises rake logic and summation logic which generates the refined matched-filter detection statistics based on the relation

$$y_k^{(n+1)}[m] = A_k^{(n)2} \cdot \hat{b}_k^{(n)}[m] + y_{res,k}^{(n)}[m]$$

wherein

$A_k^{(n)2}$ represents an amplitude statistic,

$\hat{b}_k^{(n)}[m]$ represents a soft symbol estimate for the k^{th} user for the m^{th} symbol period ,

$y_{res,k}^{(n)}[m]$ represents a residual matched-filter detection statistic for the k^{th} user, and

n is an iteration count.

8. In the system of claim 1, the further improvement wherein the refined matched-filter detection statistic for each user is iteratively generated.

9. In the system of claim 1, the further improvement wherein the refined matched-filter detection statistic for at least a selected user is generated by a long-code receiver.

10. In the system of claim 1, the improvement wherein the first and second logic elements are implemented on any of processors, field programmable gate arrays, array processors and co-processors, or any combination thereof.

11. In a spread spectrum communication system of the type that processes one or more user spread-spectrum waveforms, each representative of a waveform associated with a respective user, the improvement comprising:

a first logic element which generates an estimated composite spread-spectrum waveform that is a function of estimated user complex channel amplitudes, time lags, and user codes,

a second logic element coupled to the first logic element, the second logic element generating a residual composite spread-spectrum waveform a function of a composite user spread-spectrum waveform and the estimated composite spread-spectrum waveform,

one or more third logic elements each coupled to the second logic element, the third logic element generating a refined matched-filter detection statistic for at least a selected user as a function of

(i) the residual composite spread-spectrum waveform and

(ii) a characteristic of an estimate of the selected user's spread-spectrum waveform.

12. In the system of claim 11, the further improvement wherein the characteristic is at least one of an estimated amplitude, an estimated delay lag and an estimated symbol associated with the estimate of the selected user's spread-spectrum waveform.

13. In the system of claim 11, the improvement wherein the spread-spectrum communications system is a code division multiple access (CDMA) base station.

14. In the system of claim 13, the improvement wherein the CDMA base station comprises long-code receivers.

15. In the system of claim 11, the improvement wherein the first logic element further comprises arithmetic logic which generates the estimated composite spread-spectrum waveform based on the relation

$$\hat{r}^{(n)}[t]=\sum_{r} g[r]\rho^{(n)}[t-r],$$

wherein

$\hat{r}^{(n)}[t]$ represents the estimated composite spread-spectrum waveform,

$g[t]$ represents a raised-cosine pulse shape.

16. In the system of claim 15, the further improvement wherein the first logic element comprises arithmetic logic which generates an estimated composite re-spread waveform based on the relation

$$\rho^{(n)}[t]=\sum_{k=1}^{K_v}\sum_{p=1}^{L}\sum_{r}\delta[t-\hat{\tau}_{kp}^{(n)}-rN_c]\cdot\hat{a}_{kp}^{(n)}\cdot c_k[r]\cdot\hat{b}_k^{(n)}[\lfloor r/N_k\rfloor],$$

wherein

K_v is a number of simultaneous dedicated physical channels for all users,

$\delta[t]$ is a discrete-time delta function,

$\hat{a}_{kp}^{(n)}$ is an estimated complex channel amplitude for the p^{th} multipath component for the k^{th} user,

$c_k[r]$ represents a user code comprising at least a scrambling code, an orthogonal variable spreading factor code, and a j factor associated with even numbered dedicated physical channels,

$\hat{b}_k^{(n)}[m]$ represents a soft symbol estimate for the k^{th} user for the m^{th} symbol period,

$\hat{\tau}_{kp}^{(n)}$ is an estimated time lag for the p^{th}th multipath component for the k^{th} user ,

N_k is a spreading factor for the k^{th} user,

t is a sample time index,

L is a number of multi-path components.,

N_c is a number of samples per chip, and

n is an iteration count.

17. In the system of claim 11, the improvement wherein the second logic element comprises summation logic which generates the residual composite spread-spectrum waveform that based on the relation

$$r_{res}^{(n)}[t] \equiv r[t] - \hat{r}^{(n)}[t],$$

wherein

$r_{res}^{(n)}[t]$ is the residual composite spread-spectrum waveform ,

$r[t]$ represents the composite spread-spectrum waveform,

$\hat{r}^{(n)}[t]$ represents the estimated composite spread-spectrum waveform,

t is a sample time period, and

n is an iteration count.

18. In the system of claim 17, the further improvement wherein the estimated composite spread-spectrum waveform is pulse-shaped and is based on the user spread-spectrum waveform.

19. In the system of claim 18, the further improvement wherein each third logic element comprises rake logic and summation logic which generates the second user matched-filter detection statistic based on the relation

$$y_k^{(n+1)}[m] = A_k^{(n)^2} \cdot \hat{b}_k^{(n)}[m] + y_{res,k}^{(n)}[m],$$

wherein

$A_k^{(n)^2}$ represents an amplitude statistic,

$\hat{b}_k^{(n)}[m]$ represents a soft symbol estimate for the k^{th} user for the m^{th} symbol period,

$y_{res,k}^{(n)}[m]$ represents the user residual matched-filter detection statistic for the m^{th} symbol period, and

n is an iteration count.

20. In the system of claim 11, the further improvement wherein the refined matched-filter detection statistic for each user is iteratively generated.

21. In the system of claim 11, the improvement wherein the logic elements are implemented on any of a processors, field programmable gate arrays, array processors and co-processors, or any combination thereof.

22. A method for multiple user detection in a spread-spectrum communication system that processes long-code spread-spectrum user transmitted waveforms comprising:

generating a residual composite spread-spectrum waveform as a function of an arithmetic difference between a composite spread-spectrum waveform and an estimated spread-spectrum waveform,

generating a refined matched-filter detection statistic that is a function of a sum of a rake-processed residual composite spread-spectrum waveform for a selected user and an amplitude statistic for that selected user.

23. The method of claim 22, comprising generating a refined matched-filter detection statistic that is a function of a sum of a rake-processed residual composite spread-spectrum waveform for a selected user and an amplitude statistic for that selected user multiplied by a soft symbol estimate.

24. The method of claim 22, further wherein the spread-spectrum communications system is a code division multiple access (CDMA) base station.

25. The method of claim 22, wherein the step of generating the residual composite spread-spectrum waveform further comprises performing arithmetic logic that is based on the relation

$$r_{res}^{(n)}[t] \equiv r[t] - \hat{r}^{(n)}[t],$$

wherein

$r_{res}^{(n)}[t]$ is the residual composite spread-spectrum waveform ,

$r[t]$ represents the composite spread-spectrum waveform,

$\hat{r}^{(n)}[t]$ represents the estimated composite spread-spectrum waveform,

t is a sample time period, and

n is an iteration count.

26. The method of claim 22, wherein the estimated composite spread-spectrum waveform is pulse-shaped and is based on a composite user re-spread waveform.

27. The method of claim 22, wherein the step of generating the refined matched-filter detection statistic representative of that user further comprises performing arithmetic logic based on the relation

$$y_k^{(n+1)}[m] = A_k^{(n)^2} \cdot \hat{b}_k^{(n)}[m] + y_{res,k}^{(n)}[m]$$

wherein

$A_k^{(n)^2}$ represents an amplitude statistic,

$\hat{b}_k^{(n)}[m]$ represents a soft symbol estimate for the k^{th} user for the m^{th} symbol period,

$y_{res,k}^{(n)}[m]$ represents a residual matched-filter detection statistic, and

n is an iteration count.

28. The method of claim 22, the further improvement wherein the refined matched-filter detection statistic is generated by a long-code receiver.

29. The method of claim 22, the further improvement wherein the step of generating the residual matched-filter detection statistic for an m^{th} symbol period comprises performing arithmetic logic based on the relation

$$y_{res,k}^{(n)}[m] \equiv \mathrm{Re}\left\{\sum_{p=1}^{L} \hat{a}_{kp}^{(n)H} \cdot \frac{1}{2N_k} \sum_{r=0}^{N_k-1} r_{res}^{(n)}[rN_c + \hat{\tau}_{kp}^{(n)} + mT_k] \cdot c_{km}^{*}[r]\right\}$$

wherein

$y_{res,k}^{(n)}[m]$ represents the user residual matched-filter detection statistic for the m^{th} symbol period,

L is a number of multi-path components,

$\hat{a}_{kp}^{(n)}$ is the estimated complex channel amplitude for the p^{th} multipath component for the k^{th} user,

N_k is the spreading factor for the k^{th} user,

$r_{res}^{(n)}[t]$ is the residual composite spread-spectrum waveform ,

N_c is the number of samples per chip, and

$\hat{\tau}_{kp}^{(n)}$ is the time lag for the p^{th} multipath component for the k^{th} user ,

m is a symbol period,

T_k is a channel symbol duration for the k^{th} user,

$c_{km}[r]$ represents a user code comprising at least a scrambling code, an orthogonal variable spreading factor code, and a j factor associated with even numbered dedicated physical channels.

n is an iteration count.